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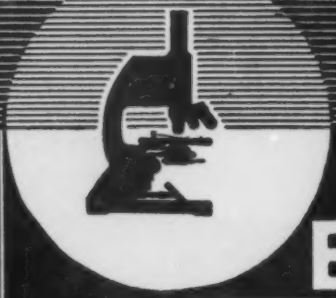

SCIENCE EDUCATION

THE SCIENCE MAGAZINE FOR ALL SCIENCE TEACHERS
FORMERLY GENERAL SCIENCE QUARTERLY

An Evaluation of Outcomes of Science in Higher Education

Needed Re-Evaluation of Certification Requirements for Biology Teachers

Mathematics and Physics

An Indoor Science Trip

Can Learning Bring About Changes in Overt Behavior?

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NUMBER 3

NOVEMBER 1943

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Science Education

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Science Education

AN EVALUATION OF OUTCOMES OF SCIENCE IN HIGHER EDUCATION *

MAURICE CARL FLEMING

1st Lt. C.A.C., Army of the U. S.†

Evidence obtained from various sources suggests the conclusion that the objectives of science should be much more inclusive than the mere recall of factual knowledge. From the apparently acceptable literature in the field, it would seem that these objectives involve the improvement of students in understandings, in the ability to use the scientific method and to develop attitudes which are scientific, in addition to the recall of factual information.

It is frequently pointed out in the literature that because it is often difficult to evaluate the various "hard-to-measure" objectives of science is no valid reason why attempts should not be made continually to evaluate these objectives in an increasingly scientific manner. In fact one might conclude that research in education which involves such evaluation is greatly to be desired.

In accordance with these conclusions this investigation proposed to determine to what extent each of the larger stated objectives for a course in Science in Higher Education was actually achieved. By an analytical study of the results it was possible to determine some of the characteristics of groups of students which showed various amounts of growths in each objective evaluated. This research was not concerned with a comparison of methods of instruction but was a quantitative study of what growths were brought about in the students by means of a course, known as "Orientation in Biological Science." The method used was that normally involved in the instruction of undergraduate college students in the situation referred to in this report.

THE PROBLEM

This investigation proposed to measure, analyze, and evaluate certain growths of college students in (1) recall of specific information, (2) understanding of generalizations, (3) elements of problem solving, and (4) scientific attitudes, which are brought about by means of the activities in the course, entitled Orientation in Biological Science, as taught during one semester in the manner in which the course is normally conducted.

RELATED STUDIES

Most of the related studies have been conducted at grade levels below that of college. On the college level there is sufficient evidence to indicate that the correlation between achievement in one objective and some other objective of the same course is not very high. Most of such reported correlations are about $r = .45$. There appears to be general agreement that a science course for general education should attempt to improve students in the objectives of this study but there is considerable

* Based on a Doctor of Philosophy thesis entitled, *An Analytical Study of Certain Outcomes of a Course for Orientation in Biological Science at College Level*, completed in the School of Education, New York University, 1942 (unpublished).

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doubt as to whether such improvement can be brought about by any science course.

A study, at any level, has been considered pertinent to this investigation when it made a contribution to one or more major aspects of the study. The background obtained from these previous studies was employed in stating the conclusions and implications of this investigation.

SOURCES OF DATA

A measuring instrument designed to measure each of the four objectives of this study was constructed and evaluated. A large number of items was obtained. Many of these had been previously used in the course and retained as desirable. All items appeared to the investigator to be suitable. These items were administered to students similar to those involved in the main study. From these results, items were selected or rejected on the basis of their "internal validity" and "index of difficulty." The items for measuring scientific attitudes were selected from five attitude scales which had been previously developed by others. A two-column arrangement was devised to measure both what attitudes the student personally accepted and his knowledge of scientific attitudes.

Several revisions of the measuring instrument were made on the basis of results obtained from repeated administration of the measuring instrument. A preliminary study was conducted and this allowed for the final revision of the measuring device as well as provided valuable suggestions for conducting the main study. The key for the test was developed by two instructors who worked with the investigator for this purpose.

On the basis of the results of the use of the measuring instrument as a pretest in the main study its reliability was determined. This was done by using the split-half technique to determine the coefficient of reliability for each part and then for the instrument as a whole. Since this coefficient was .83, the reliability appeared to be satisfactory. It was determined that the validity of each part, as well as the whole measuring device of two hundred and twenty-five items, was also satisfactory. For this purpose use was made of (1) the selection of items on the basis of internal validity, (2) a professional jury to judge certain parts, (3) a jury of advanced graduate students in science education who responded to the items of the attitude scale, and (4) the careful selection of factual items from the material of the course.

PROCEDURE

The measuring instrument was administered to both the experimental and control groups in September, 1941. The college students were undergraduates of the School of Education, New York University. The experimental group consisted of 148 students who took a course in orientation in biological science for one semester using normal teaching procedures. Eighty students "who did not take this or any similar science course during the semester of this experiment" composed the control group. On the basis of these pre-test scores the groups were equated by the group method to the extent that there was no statistically significant difference between their means or standard deviations for scores on five different objectives. These objectives involved mental abilities, facts, understandings, elements of problem solving, and scientific attitude.

During the semester of the study the experimental group was taught by the investigator and one other instructor. The procedures used were standardized and were carefully recorded in a log of the activities of the course. The Henmon Nelson Test of Mental Ability for College Students—Form A, was used to measure mental ability of each student of both groups. A personal data blank, which was constructed for the purpose, was used to obtain significant personal data. Special additional records were kept of the students in the experimental group. These various data together

with the scores on the pretest and the final test formed the basis of the findings.

In this study the same measuring instrument, which had been proved valid and reliable, as previously described, was administered before and after the experimental period of one semester. As a supplementary study one section of the experimental group was studied further as those students completed a four-point course instead of two points since they met for two two-hour meetings per week for fifteen weeks instead of one two-hour meeting per week as was the case with most of the experimental group.

THE FINDINGS

The results and possible implications of this investigation are presented in the form of generalized statements based upon the experimental group unless otherwise stated. These statements are as follows:

1. The instruction in this course brought about growths in each objective measured, and these growths were of sufficient amount that they were statistically significant in each case. This was based upon three subordinate findings: (a) the scores on all objectives in the experimental group were improved to a significant extent, (b) the scores on all objectives in the case of the control group were also improved but the significance of the improvement was much more limited than in the case of the experimental group, and (c) the differences between the growths of the two groups were statistically significant with but one possible exception.

2. Of the following three objectives most growth appears to have been made in recall of facts ($8.2 \pm .59$), the next most improvement in understanding of generalizations (4.3 ± 62), and least in elements of problem solving ($2.6 \pm .39$).

3. The variability of the group for the objectives involving recall of facts and the scientific attitude were significantly reduced by the instruction, since the variability did not change to a significant degree for any objective in the control group.

4. Both persons who took science and those who did not made growth in each objective.

5. The students involved in this course are quite a heterogeneous group in regard to age, year in college, vocation, field of major interest, and previous science.

6. Students appeared to possess, and to maintain through this course, superior knowledge of what attitudes are scientific as compared to what attitudes they personally accept.

7. In growth of attitudes the difference between the students' mean gain in knowledge of the attitude $3.6 \pm .88$ and what attitudes the students personally accepted 2.3 ± 62 was not great but in favor of the knowledge of the attitude.

8. Correlations of scores on these objectives for the first and second test have a rather narrow range ($.32 \pm .05$ to $.65 \pm .03$), none of which is high.

9. All students had taken some previous science with the average student having had a fairly good science background (2.3 years in high school and 1.9 semesters in college).

10. Although there were mean gains which were statistically significant for each of the objectives in the experimental group, there were for each objective individuals who scored lower on the second application of the test.

11. A student's score on the mental ability test used and his score on various objectives measured were correlated only to a very limited extent ($r = .07 \pm .05$ to $.34 \pm .05$), while the correlations between mental ability scores and growths in each objective were negligible ($r = -.16 \pm .05$ to $.07 \pm .05$).

12. The correlation for final scores on the factual test and other abilities did not vary greatly ($r = .37 \pm .05$ to $.57 \pm .04$)

and were all low except with elements of problem solving which was marked.

13. The score on the factual test could not have been used to predict with any great accuracy the students' rank, among the group, on any other objective ($r = .37 \pm .05$ to $.57 \pm .04$).

14. No ability had a high correlation for the final scores on that ability and gains in the same ability while the range of correlations was rather limited ($r = .37 \pm .05$ to $.56 \pm .04$).

15. Correlations for gains in any ability with gains in any other ability were so low as to be negligible ($r. = -.11 \pm .05$ to $.20 \pm .05$).

16. Scores on the attitude objectives tended to show a lower correlation with other objectives than was the case with any other pair of objectives.

17. There was not a high correlation between the students' scores on the attitudes personally accepted and knowledge of what attitudes were scientific ($r = .44 \pm .04$ for the pre-test and $.60 \pm .04$ for the final test).

18. None of the final test scores on any one objective correlated very highly with scores on any other objective, although all were positive and with a rather wide variation ($r = .08 \pm .05$ to $.60 \pm .04$).

19. Those persons who ranked in the lower groups according to mental ability showed larger growths in the objectives involving understandings, problem solving, and scientific attitudes (personally accepted) than did persons of higher mental ability.

20. Those students who received the lower rankings on out-of-class assignments tended to make smaller growths in objectives measured.

21. Persons who had completed least previous science, persons who were younger, and persons who were in the lower classes made most growth in abilities measured.

22. There appears to be little connection between the student's score on mental ability and his growth in these various objectives.

23. Older students and ones in the upper classes in college tended to show a greater growth in the objective involving the scientific attitude.

24. The supplementary study tended to show that it makes no significant difference, in growths made, whether this course is presented two hours per week for fifteen weeks or four hours per week for a period of seven and one-half weeks.

25. No significant growth was measured for the second half of the course for the supplementary study but the evidence indicated that this was because giving the same test three times in one semester was too often.

26. Measurable and statistically significant growths, in each of these objectives, can be brought about by means of instruction in science in as short a period of time as the work of a one-semester course even if that work is concentrated into a period of seven and one-half weeks.

SOME CONCLUSIONS

If one is interested in knowing a student's achievement or growth in any objectives other than recall of factual information, then it is necessary to specifically evaluate each objective being considered. It appears that there is little or no justification for evaluating the student's achievement or growth in one objective and then assuming that the student would perform equally well in any other given objective.

Perhaps the recall of factual information is the objective most often evaluated in actual situations and from this one source the members of the group are rated. In order to work on this basis it would be necessary to admit that practically nothing was known about any ability except the one specifically evaluated which in most cases is the recall of facts. Even if mental ability scores are available it would appear that they would be of very little use in determining achievement in any of the various

objectives. In view of the fact that the literature indicates wide agreement on the objectives of science in general education then this study strongly suggests a much wider use of test items designed to measure objectives other than recall of factual knowledge.

It appears, from this study, that a student might have considerable knowledge of what attitudes are scientific and at the same time not personally accept these same attitudes which he knows to be scientific. Unless some provision is made to obtain the student's true reaction, what would be obtained by an instrument designed to measure a student's attitude would be some combination of what he personally accepted with what he knew should be accepted. Some arrangement such as was used in this investigation, where the student is required to give both his personal reaction and what he knows to be a scientific reaction in each situation, would seem to be required.

It is often questioned whether certain objectives can be obtained in a limited period of time. This question has tremendous practical significance since it involves the possible value of various types of intensive courses given in a rather limited period. While a complete study of this problem was not involved in this investigation some indication of an answer was obtained. It is significant that no evidence was obtained to indicate that it made any significant difference whether the course was an intensive one or the same course was spread out over twice the period of time.

Questions are often asked as to whether the objectives of science can be achieved as well by students of various ages and with varied amounts and kinds of experiences. One particular form in which these questions are put is to the effect of whether older, more experienced students improve to any significant extent in these objectives and most especially in the development of a more scientific attitude. The findings indicated only a slight correlation between age of the student and growths in each of the objectives measured. In fact no general trend could be found since in some objectives the older students made even greater improvement than the younger ones in the same situation. Since it appears true that students of practically any age do improve in these objectives then there is sound basis for offering such courses for students without fear that their advanced age or level of maturity would in themselves be great enough to defeat the purpose of the course.

FURTHER RESEARCH SUGGESTED

The study here reported presented a number of related problems which need to be investigated. Some of these are:

1. A determination of the rate of growth in these various objectives;
2. The development of satisfactory means of measuring attitudes in science which are simple enough to score for use in normal teaching situations;
3. A determination of whether the period of time covered by a course affects the outcomes;
4. A search for evidence as to how the possession of various objectives is related to behavior;
5. The connection between growths in various objectives and retention of those objectives;
6. The selection of subject matter most suitable for developing objectives in science in addition to a mere recall of factual information;
7. The measurement of the student's ability to judge his own growth in various objectives;
8. Possible ways of measuring various objectives by such ordinary short answer questions as true-false, multiple choice, matching and modified completion;
9. A determination of possible objectives, other than those usually presented, which may be desirable as proposed outcomes for courses in science.

Research involving the types of outcomes to be desired would seem to be especially

important in this time of war. At present it will be necessary to reevaluate the program of science as it is offered to those who remain at home during this world crisis. Particular attention should be paid to development of the type of science which will meet the needs of the millions of men and women now in the armed forces when victory has been attained and their attention is again turned to civilian education.

NEEDED RE-EVALUATION OF CERTIFICATION REQUIREMENTS FOR BIOLOGY TEACHERS

WILLIAM ALBERT EARL WRIGHT

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INTRODUCTION

In general, certification requirements for teachers, particularly on the junior and senior high school levels, lag behind the progress of research and experimentation which lead to alteration and variation of the existing aims, objectives, and methods of teaching of the various subjects contained in the curricula of secondary schools.

For the past several decades, the emphasis upon the teaching of biology has been directed towards the conception of biological study as the study of living organisms. Syllabi, textbooks, laboratory manuals, and textbooks on the methods of teaching biology have been revised with this objective in mind. In actual teaching practice, however, the objectives influenced by the above conception of biological study have been only partially achieved.

OBJECTIVES PARTIALLY ACHIEVED IN TEACHING PRACTICE

Why has teaching practice in biology failed to reach the objectives evolved several decades ago? It is probably due partly to the failure of the staff members of biology departments of colleges and universities engaged in the preparation of biology teachers for the public schools to place the proper emphasis upon the field ecology of plants and animals or field biology as necessary equipment for the successful biology teacher. Students majoring in the biological sciences have, also, failed to recognize the importance of a thorough training in the field ecology of plants and animals as necessary training for teaching a "living biology." College administrative authorities, charged with the responsibility of constructing class schedules, have frequently neglected to schedule biology laboratory periods so that sufficient time is available for field trips without transgressing upon the time assigned to other classes.

The above reasons, although probably representing the major reasons for the apparent lack of emphasis upon field ecology or field biology, do not provide a complete understanding of the situation. Certain other minor factors must also be considered at this point. Frequently, college or university students enter upon the study of biology with the intention of entering medical or dental schools or pursuing other non-teaching careers at the conclusion of their undergraduate work. Admirably prepared for laboratory positions in biology, career plans are altered near the conclusion of their undergraduate work and the courses in education required for certification to teach biology are hastily elected so that they may accept positions as teachers of biology in the secondary schools. Another factor which conditions the emphasis upon field ecology has been too infrequently publicized. Extra-curricular activities frequently deter students from enrolling in bi-

ology courses which require any considerable amount of time to be devoted to field trips since, probably, the afternoon periods are most preferable for the scheduling of these courses due to the minimum of interference with other classes. Field trips, even though limited to within comparatively short distances from the campus, may cause students to lose part of the afternoon schedule assigned to practice of various athletic teams, dramatics, musical organizations, and various other extra-curricular activities.

IMPORTANCE OF ECOLOGY TO THE STUDY OF BIOLOGY

Field ecology has long been recognized, even though in actual practice it has been frugally used, to be the most important factor in the teaching of a "living biology." Field ecology teaches students to recognize and think of plants and animals with reference to their environment.

Since ecology, also, treats of the distribution of plants and animals, the prospective teacher of biology learns where the various forms of plant and animal life may be found. This knowledge is absolutely invaluable since the biology teacher is able to conduct secondary school students intelligently and skillfully on field trips and to supplement or to substitute living specimens for the preserved specimens in the laboratory.

Finally, field trips assist the student in developing an appreciation of nature which can not be approached by any other method and provides a means of sustaining a profound interest in the study of biology.

REQUIREMENT OF FIELD ECOLOGY FOR CERTIFICATION OF BIOLOGY TEACHERS

Since the emphasis upon the teaching of biology has been directed towards the conception of biology as the study of living organisms, should not the certification requirements for biology teachers in the various states be changed to insure the proper emphasis upon this fundamental conception?

How could certification requirements for biology teachers be changed to more fully achieve the objective of teaching a "living biology"? This problem could easily be solved by amending existing certification laws or regulations to include either one of two possible alternatives or a combination of both.

First, the prospective biology teacher could be required to submit a transcript indicating that a minimum of three semester hours has been completed in field ecology. Second, individuals wishing certification in biology could be required to present a signed statement from a college or university administrative officer that the biology courses submitted represent the desired number of clock hours spent in supervised field work. Third, biology certification could be restricted to those individuals who are able to present evidence of having completed the required number of semester hours in field ecology as well as the required number of clock hours in supervised field trips.

MATHEMATICS AND PHYSICS *

H. EMMETT BROWN

Teacher of Science, Lincoln School, Teachers College, Columbia University

SOME DATA

Let us begin by considering three different situations in which we may commence to see something of the role that mathematics plays in the physics classroom.[1]

Situation No. 1

We are using a hammer. On one occasion as it descends the head is moving at the rate of 30 feet per second. If the head weighs ½ pound we obtain a value of a trifle over seven by substituting in the formula, $\frac{WV^2}{2g}$. Seven what? Why seven foot-pounds. We round off our figure at this value.

If we stop our considerations at this point we have succeeded only in helping the student to develop skill in manipulating the formula. Let us, therefore, go further.

This seven foot-pounds is kinetic energy. And energy is defined as "ability to do work." We measure work by the product of force and distance. This means that the seven foot-pounds of energy possessed by the hammer may be used in driving a small nail a relatively long distance, or a spike a short distance. But enough. The hammer has hit the nail. Measurement reveals that the nail has been driven in a half inch. The energy equation becomes:

7=Force×distance; 7=F×1/24 (½ in.=1/24 foot). Solving, F=168 pounds. That is, the average force exerted by the hammer on the nail is that of a stationary weight of 168 pounds.

We pull back the hammer to deliver another blow. The head descends at the same speed as before. But this time, alack, our aim is poor and the hammer hits not the nail of steel, but the one on the end of our thumb. Unfortunately, too, that thumb is resting against an unyielding surface. The nail can "give" but a very short distance—about a thirty-second of an inch, that is about 1/400 of a foot. Now our energy equation is:

7=F×1/400 and F=2800 pounds.

A force of nearly a ton and a half has momentarily pressed against our nail! Is it any wonder that a few days or weeks later we lose the nail?

Now this is only one series of mathematical experiences but it should be apparent that we are commencing to build up understandings concerning the meaning of kinetic energy and work and of the interconvertibility of energy forms. Note that in order to achieve our purposes we went beyond the treatment accorded the topic in most texts. Far better to treat the kinetic energy in a purely descriptive fashion than to employ the usual incomplete mathematical development.

Situation No. 2

Newton's Third Law of Motion is stated simply as: "To every action there is an equal and opposite reaction." Now just what does this mean? Let us consider the case in which a cartridge is being shot from a rifle. Visualize the shell traveling down the rifle barrel impelled by the force of expanding gases. Evidently the force exerted on the shell (F_s) equals the force exerted backwards on the rifle (F_r); similarly the length of time during which this force is being exerted is the same in the two cases. We make a table showing the equalities obtained so far:

Shell	Rifle
F_s	F_r
t_s	t_r

and, of course,

$F_s \times t_s$	$F_r \times t_r$

From Newton's Second Law of Motion we know that, in general, F=Wa/g. We substitute for F, using appropriate subscripts, in the above expressions and obtain two new expressions to insert in our table. They are: $W_s a_s t_s/g$ and $W_r a_r t_r/g$. But from the work on accelerated motion we know that v=at. Again substituting with appropriate subscripts, we obtain two more equal expressions which, when inserted in the table make it appear as follows:

Shell	Rifle
F_s	F_r
t_s	t_r
$F_s \times t_s$	$F_r \times t_r$
$W_s \times v_s$ / g	$W_r \times v_r$ / g

* Paper presented to the New York Society for the Experimental Study of Education, March 20, 1943.

[1] The first two of the following illustrations have been taken from a previous article:

Brown, H. Emmett. "Mismanaged Mathematics." *School Science and Mathematics* 40:368–76; April, 1940.

I have also drawn somewhat in other portions of this article from a still earlier writing in this field:

Brown, H. Emmett. "Mathematics in Physics." *National Council of Teachers of Mathematics, 6th Yearbook*, p. 136–164.

To these last two expressions in each column, definite names have been given. They are impulse (Ft) and momentum (Wv/g). In this case we may therefore replace the less precise terms "action" and "reaction" by more definite "momentum of the shell," "momentum of the rifle" and "impulse of the shell," "impulse of the rifle."

In conjunction with work done previously we can now refine notions of kinetic energy and momentum, terms which are commonly confused. In the previous problem we equated energy to work (F×d). Now we equate momentum to impulse (F×t).

In order to make the point clear let us take the case of a boy sliding down hill. Sled and boy weigh 120 pounds. At the bottom of the hill they are moving at the rate of 16 feet per second. Calculating, we learn that the kinetic energy is 480 foot-pounds; momentum has the numerical value of 60 pound-seconds. Let us suppose that the force of friction on the level surface onto which the sled now goes is six pounds. How far will the boy go? Why 80 feet? (480=6×d; d=80.) For how long a time will he move? Why, 10 seconds? (60=6×t; t=10.)

Thus we can enrich our notions of kinetic energy and momentum by the following:

Kinetic energy is the measure of the DISTANCE *that a moving body will continue to move against a constant retarding force. Momentum is the measure of the* TIME *that a moving body will continue to move against a constant retarding force.*

By our mathematical development we have at once made the Third Law of Motion more understandable and have also further clarified our notions of momentum and kinetic energy.

Situation No. 3

We are dealing with the forces acting on an object moving in a circular path. We wish to show the relationship between the various factors affecting the centrifugal force. The class performs three simple experiments in which rubber stoppers are whirled at the end of strings. In these experiments they note how hard the string pulls on their fingers as:

1. Two stoppers of different weights but with strings of the same length are whirled at the same rate of speed.
2. A single stopper is whirled at different rates of speed, but with the string of constant length.
3. A single stopper is whirled with as nearly as possible a constant *linear* speed but with varying lengths of string.

Evidently we are studying the effect of the factors *mass, radius,* and *velocity,* upon the centrifugal force. Three equations may be set up to show these relationships:

C.F. $\propto$ m, i.e. Centrifugal force varies directly as some power of the mass.
C.F. $\propto 1/r$, i.e. Contrifugal force varies inversely as some power of the radius.
C.F. $\propto$ v, i.e. Centrifugal force varies directly as some power of the velocity.

Note the form of the explanatory statement. The experiments are too lacking in precision of measurement to reveal other than the general character of the variation.

Each of the above equations evidently implies that the other quantities are constant. It is not difficult by mathematical illustrations to show that if all the quantities vary together, then,

$$C.F. \propto mv/r.$$

But bear in mind we do not know the exponents that m, v, and r should have. Let us leave the realm of ordinary high school work and approach the problem from a different angle.

A general equation involving these three variables and centrifugal force might be:

(1) $C.F.=K m^x v^y r^z$. (Do not be concerned over the fact that r is not placed in the denominator. Z may have any value, negative as well as positive.) The problem becomes one of the assigning values to x, y, and z so that the product of the three quantities may be expressed in terms of three basic quantities, or *dimensions*—length, mass, and time (l, m, t). Let us express each of the above quanties in terms of these basic dimensions. Because force=mass x acceleration, centrifugal force has the dimensions: $m \times \frac{l}{t^2}$ or $m^1l^1t^{-2}$.

Mass cannot be expressed more simply, velocity has the dimensions $\frac{l}{t}$ and the radius has the dimension l. Hence, since K, a constant, has no physical dimensions, equation (1) may be written

(2) $m^1l^1t^{-2}=m^x\left(\frac{l}{t}\right)^y l^z$

or

(3) $m^1l^1t^{-2}=m^xl^{y+z}t^{-y}$.

By comparing the exponents of m, l, and t we obtain the following equations in x, y, and z:

$1\ (\text{unity})=x$
$1\ (\text{unity})=y+z$
$-2=-y$

Hence, solving, x=1, y=2, and z=—1.

Substituting these values of x, y, and z in equation (1) we have

(4) $C.F.=Km^1v^2r^{-1}$ or $K\frac{mv^2}{r}$.

Subsequent work can easily establish the fact that with the proper consistent units, K has the value of 1, or convert the equation into the form more useful for high school use, of

$$C.F.=\frac{Wv^2}{gr}.$$

THE CONTRIBUTION OF MATHEMATICS TO PHYSICS

A study of the above three illustrations, and of some of the many other situations in which mathematics plays a part in physics would reveal, I think, five ways in which mathematics functions in the field of physics. These are:

1. *Mathematics may show relationships between different divisions of the subject.* Similarities and differences between kinetic energy and momentum may be made clear. The calculation of the efficiency of an electric motor relates the work in electricity to the earlier consideration of efficiency.

2. *The use of mathematics may clarify and enrich the understandings and concepts of physics.* The calculations involving the hammer descending on the nail surely are of this class. At the risk of making this section disproportionately long, I am tempted to show how the use of mathematics can bring into sharp relief what it is that a machine may do for us. This illustration has been taken, but with slight modification, from Polakov, W. N. *The Power Age.* It is desired to hoist bricks to the top of a building under construction. Two methods are available. In one, a man places the bricks in a hod, and carries them, 100 pounds at a time to the top of the building, hoisting his body to the same height as he does so. He then returns with the empty hod and repeats the process. The alternative is to place the bricks on the platform of a windlass and crank up a much larger load of bricks, 400 pounds say, to the top of the building, 100 feet above the ground. Making reasonable allowances for the weight of the man, the hod, and the windlass platform, a tabulation of the results at the end of a day's work would read:

	With Hod	With Windlass
Work done per ton..	520,000 ft. lbs.	325,000 ft. lbs.
Work done per hour	130,000 ft. lbs.	162,500 ft. lbs.
Load lifted in 8-hour day.....	2 tons	4 tons
Work done in 8-hour day.....	1,040,000 ft. lbs.	1,300,000 ft. lbs.

A study of the table reveals:

1. In a full day, the machine exacts 260,000 foot-pounds more work from the man than he would do without it.
2. For the same amount of work done in each case, say 1,000,000 foot-pounds, the man with the hod can lift 1.92 tons while the man using the windless can lift 3.08 tons. In lifting any given weight of bricks he can do the job in one-half the time.

Thus the use of the machine makes it possible to do the same amount of work in less time. But does it save work? It is true that working with the machine, the man would do less work per ton than when he used the hod—mainly because the man has to lift his own body along with the bricks in the latter case. But let us not forget that the work we are really desirous of doing is to raise the bricks—to raise a ton of bricks, 2000 pounds, a distance of 100 feet. That is to do 200,000 foot-pounds of work. Compare this amount with the first line of the table. 325,000 foot-pounds to accomplish 200,000 foot-pounds? Evidently this machine, at least, does not *save work.*

3. *Mathematics may make clear the character of the units—the dimensions if you please, of the units in which physical quantities are measured.* The work with centrifugal force in the third illustration was evidently directed to that purpose. Let us take another illustration also. We are trying to make clear the notion of the volt. We imagine that we are moving a negatively charged body from the neighborhood of a larger, positively charged

body. To do this requires that work be done. It seems reasonable that the more the charge on the negatively charged body, the more the work that will be done. Double the charge, double the work; triple the charge, triple the work. In general $W \propto Q$, where Q is the quantity of the charge on the body. Similarly, the further out we move the negatively charged body the more work there will be done. The thing that is significant here is not the distance, but the difference in electrical potential through which the negatively charged body is moved. The greater this difference, the greater the amount of work done. That is $W \propto V$. If both Q and V vary, $W \propto QV$ or $W = KQV$. By properly defining Q and V, K may equal unity and $W = QV$. Hence $V = W/Q$. That is voltage measures the work done per unit quantity of electricity.

4. *The use of mathematics may show the direct and practical application of physics to practical situations.* The gunner, trying to train his piece on the distanct enemy uses mathematical tables worked out on the basis of physical laws. The theoretical path of the shell may be determined by calculating the amount of departure from the direction along which the gun is sighted, and along which the shell first starts its journey, using the equation $S = \frac{1}{2} gt^2$. The determination of the actual path makes use of other physical principles in their precise, that is their mathematical application. Or again, the student who wishes to use a variable rheostat of the slide-wire type as a potentiometer will, if he is wise, make a short calculation involving Ohm's Law to see if the current the device will draw when connected to the 120-volt power line is within the limit indicated on the instrument.
5. *A mathematical expression is often the form into which generalizations based upon a series of physical measurements are cast.* Suppose that we make some measurements upon the frequency of the note produced by a vibrating string as we vary its length. We may obtain data such as the following:

Length of String	Frequency
100 cm.	256 v.p.s.
80.5	320 v.p.s.
66.2	384 v.p.s.
50.4 cm.	512 v.p.s.

Evidently some sort of inverse relationship is involved. We can check this by dividing each of the lengths *by* the length of the first string and similarly dividing each of the frequencies *into* the original frequency. Note the reversal in the order of these operations. In order to assist in the establishment of the basic law, let us designate the successive lengths by L_1, L_2, L_3, L_4 and the successive frequencies by N_1, N_2, N_3, N_4. Then the ratios just calculated become:

$L_1/L_1 = 1.000$	$N_1/N_1 = 1.000$
$L_2/L_1 = .805$	$N_1/N_2 = .800$
$L_3/L_1 = .662$	$N_1/N_3 = .667$
$L_4/L_1 = .504$	$N_1/N_4 = .500$

A simple inverse relationship is indicated—a relationship which can be stated in the form $N_1/N_2 = L_2/L_1$ where these symbols indicate any corresponding pairs of values. The use of the mathematics in this case at once suggests the generalization, thus algebraically stated, and emphasizes the fact that this relationship *has not been proved.* The data merely make the generalization seem a reasonable one.

THE CONTRIBUTION OF PHYSICS TO MATHEMATICS

The contribution that mathematics may make to physics is evidently a most generous one. But is the process reciprocal? May physics make a contribution to mathematics? Of course. Many forward looking mathematics teachers bewail the fact

that much mathematics is taught in a vacuum, as it were. The mathematical manipulations are those which involve mere numbers—numbers devoid of physical or other significance. A solution would seem to be the more generous use of real data in their problems—of problems based upon physical situations among others. Let us see what this might mean in some of the usual mathematics courses.

In elementary algebra direct work with the use of beam balances would help to clarify the operations with equations. Barographs and thermographs could be used in connection with graphing; thermometers with their positive and negative readings in connection with signed numbers. The significance of ratio and proportion may be developed by a study of the metric system. Many modern alegbras discuss the lever. Why not have the class actually experiment with these devices?

The physics topics which bear upon the field of geometry are many indeed. Let us list a few of them. The study of forces involves the use of triangles and parallelograms. The center of gravity of a geometric shaped piece of metal may be determined experimentally and its position checked by geometric construction and proof. Construction of images may be made by geometric means and the proofs of simple optical formulas worked through.

Physics material has little to offer in the usual trigonometry course, save for the simple sine relationship (usually taught in algebra) involved in the index of refraction and some use of functions in connection with problems such as that of a shell trajectory. However in more advanced courses in differential and integral calculus the connection is close once again. Experience with objects undergoing accelerated motion may be used to clarify the notions of the first derivative of distance with respect to time (velocity) and the second derivative (acceleration). Work with almost any one of the physical coefficients (linear expansion, mutual inductance, self inductance, thermal conductivity) as well as with simple harmonic motion will also help to show the meaning of the derivative.

In the integral calculus the opportunities to use physics seem even richer. Among the physics areas thus of value are: kinetic energy both of translation and rotation, alternating current calculations and experimentation to show the average and effective value of alternating current voltage, moment of inertia, and a variety of experiences based upon the equation for work $W = \int F.\, ds.$

WHAT PHYSICS ASKS OF THE MATHEMATICS DEPARTMENT

By the title of this section is not meant any frenetic cry for a better teaching of mathematics. Studies such as those by Lohr, Reagan, and Kilzer[1] have shown that the number of mathematical skills needed in high school physics courses is not by any means large, and that, in general, students entering physics courses have an adequate mastery of those skills. Any difficulty they may have in solving physics problems is likely to be due to the quality of the physics teaching, the opinion of many physics teachers to the contrary, notwithstanding.

What I do wish to suggest is that certain topics and procedures, already found in many mathematics courses in the country, be more widely taught. These include:

1. Generalizing from data. Some courses in mathematics do give students opportunity to make such generalizations. What is asked is that opportunities be afforded to work with data such as that of the vibrating string

[1] Lohr, Virgil. "A Study of the Mathematical Abilities, Powers and Skills as shown by Certain Classes in Physical Science." *School Science and Mathematics* 25:834–44; 1925.

Reagan, G. W. "The Mathematics Involved in Solving High School Physics Problems." *School Science and Mathematics* 25:292–9; 1925.

Kilzer, L. R. "The Mathematics Needed in High School Physics." *School Science and Mathematics* 29:360–2; 1929.

which might be obtained in a laboratory experiment. The relationships involved in such data are not always obvious. Let us take two other cases. In the first the relationship between length and voltage drop is fairly obvious although the measured values do deviate somewhat therefrom. In the second, the fact that distance varies directly as the square of the time is only approximately realized in the data.

Length of Uniform Wire	Voltage Drop	Distance	Time
25 cm.	80 volts	15 inches	1 sec.
50 cm.	1.65 volts	53 inches	2 sec.
75 cm.	2.38 volts	120 inches	3 sec.
100 cm.	3.10 volts	204 inches	4 sec.

2. The ability to translate a statement such as "The volume of a gas varies inversely as the pressure, if temperature remain constant" into the algebraic equivalent: $V_1/V_2 = P_2/P_1$. In general the student should see that $A_1/A_2 = B_1/B_2$ is the algebraic statement of direct proportion while if the order of the subscripts of either A or B be changed, the resulting expression, such as $A_1/A_2 = B_2/B_1$, indicates an inverse proportion.
3. The ability to go from expressions such as $A \propto B$ and $A \propto C$ to the equation $A = KBC$; or $A \propto D$ and $A \propto \frac{1}{E}$ to the equation $A = \frac{KD}{E}$. The student should recognize in $A \propto B$ an alternative expression for direct relationship and in $A \propto \frac{1}{E}$ alternative expression for inverse relationship.
4. Significant figures. The student should know that if the accuracy of his physical measurements is to but three places, there is nothing gained by using a value of $\pi = 3.1416$ or in retaining more than three significant figures in any calculation—intermediate or final—based upon his measurements.
5. The slide rule. This calculating device which may well be first introduced in the junior high school should be reintroduced and used on frequent occasions in subsequent mathematics courses. Mastery of the slide rule must be to the point where the student has as complete faith, or perhaps even more faith, in his slide rule calculations than he has in the results of his multiplications and divisions done by hand. The efficacy of the instrument in rounding off answers to the level of accuracy imposed by the character of measurements in high school physics is also appreciated by the physics teacher.
6. The exponential system of expressing numbers. Students should be able to convert both large numbers and numbers smaller than one, readily and accurately into the exponential system. Thus the problem $\frac{6240}{.00038}$, is more easily worked as:

$$\frac{6.24\times10^{3}}{3.8\times10^{-4}}=1.64\times10^{7}$$

7. Frequent and increasing use of symbols other than X for the unknown should be employed in mathematics. Anathema to the physics teacher is the practice of always substituting that letter for symbols in formulae. Perhaps to the habit of associating the letter X merely with a number may be traced the vicious practice of leaving answers to physics problems as raw numbers, devoid of the physical units which give them their significance. Let us have more and better problems in mathematics, the unknowns in which are: D for dollars, A for area, N for the number of men, I for interest.
8. As a corollary to the above and to the suggestions that mathematics may well

use physics materials in its courses, is the request that more and more attention be focused in mathematics classes upon the problem of the consistency of the units used in a given problem and the units in which the answer is to be expressed. Let there be an increasing number of problems dealing with real quantities rather than with the mere manipulation of numbers, and let no answer to such a problem go with answer unlabeled both as to significance and units.

SUMMARY

In this paper I have tried to make clear the reciprocal relationship between mathematics and physics. Mathematics is a vital tool essential to the attainment of many, perhaps most, of the understandings in physics and to the skills which are developed in that area. Such being the case, arguments for or against the mathematization, or the de-mathematization of physics are beside the point. Mathematics, a tool, is used like any tool, whenever really needed, that is whenever a certain understanding or skill may be acquired more rapidly or accurately, or both, by means of the mathematical treatment. Mathematics is not used for reasons of tradition, or merely to make the subject difficult, or acceptable to standardizing agencies.

Reciprocally, through its contribution of a background of real experiences, physics has much to contribute to the field of mathematics. There is nothing sacrosanct about the subject, physics, and mathematics teachers should feel no hesitancy to incorporate into their own work such materials from physics as they feel can be used profitably. The implications of this position for the training of mathematics teachers should be evident.

For the realization of the various functions of mathematics in high school physics, the training in mathematics secured in elementary and secondary school classes, is in the main adequate. There is no real lack of fundamental skills and abilities. The mathematics department can make a still more complete contribution to physics teaching by a continuing stress on the reality of problem situations, by the introduction of certain additional topics into mathematics courses (a number of which topics are suggested in this paper) and by the direct teaching of some materials ordinarily restricted to the physics class. Everything is to be gained by a closer working relationship between the two fields.

AN INDOOR SCIENCE TRIP

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The value of science excursions as teaching devices has been often and ably discussed by many writers. (See Oxenhorn, J. M. The Excursion in the Teaching of Science. Bulletin of High Points, Vol. 23, No. 2. Feb. '41.) Such excursions, however, have always had many difficulties attached to them. Among these we might mention time, arrangement, travel, and excuses from other classes. At their very best, they have always been pedagogical luxuries, not often experienced by the teacher and pupil.

If science deals with the application of principles to our everyday environment, what more obvious devices can the science teacher use than a tour of the school building? The large modern building, of course, will lend itself more readily for this purpose than a small, comparatively older building. However, both of these can be used to great advantage.

It is suggested that the arrangement described below be followed if the teacher has never used this technique before. Later on, when he has had a chance to analyze the method, he will discover new angles and methods which will be more suitable for his type of situation.

To derive the maximum benefit from such an excursion, it should be arranged at the end of the first full year of general science. A day during the pre-Regents week is good. Such a tour can last from one to three hours, depending on the size of the building, and the details and method which the teacher uses. Pupils may be asked to come early in the morning if they are on late time, or to stay after school. It is best to mimeograph a questionnaire which the pupil fills in as the tour progresses. An assignment may be added at the end.

Below is a list of some of the things pupils may see in a school building which they should understand and appreciate to a far better extent as a result of their science study. For purposes of convenience, these have been arranged as units of location rather than units of study topics.

I. *Auditorium*
- A. Asbestos curtain; discuss its value; have pupils feel the material.
- B. Organ: discuss vibration of air; show controls.
- C. Stage lighting devices; switches.
- D. Drop cords; pulley arrangement.
- E. Projection booth; machines; lenses; color wheel.

II. *Boiler Room and Basement*
- A. Heaters: furnace; boilers; pressure gauges; discuss conversion of energy.
- B. Asbestos covered pipes; purpose.
- C. Expansion bends in pipes; how pipes are attached to ceiling.
- D. Thermostats: recall principle of mechanism.
- E. Fuse boxes; stress value.
- F. Gas and electric meters: show switches and stop cocks.

III. *The Cooking Room of Cafeteria*
- A. Refrigerator: coils, motor, arrangement of food; defrosting.
- B. Gas stove: pilot light; how to regulate it; proper mixture of air and gas; how to regulate; show how pots become smudged and how to prevent this.
- C. Broiler; heating coils.
- D. Sink trap.

IV. *Halls and Offices*
- A. Fire extinguishers: use, location, and value.
- B. Fire signal box: recall telegraph.
- C. The switchboard.
- D. How bells and gongs are rung.
- E. Ventilation shafts.
- F. Stairways: enclosed safety lights; reinforced safety glass partitions.

V. *Rooms*
- A. Thermostat.
- B. Thermometer.
- C. Univent system, structure and operation.
- D. Transom arrangement: purpose.
- E. Ventilators in wardrobes.
- F. Radiators and valves.

A tour of this sort will remove the element of mystery inherent in the running of a large school building. It will also teach the pupil the application of scientific principles in everyday life. It has the advantages of keeping pupils right inside the building rather than taking them out on a long trip. Its element of novelty for the pupils serves to stimulate them to greater achievement and the break in the monotony of routine motivates them to greater attention. To add still greater enjoyment, pupils may be encouraged to bring with them their cameras so that they may take snapshots of various interesting features.

For the teacher, it is a useful technique worthy of a fair trial. For the pupils, it may mean an invaluable experience long remembered as joyful learning.

CAN LEARNING BRING ABOUT CHANGES IN OVERT BEHAVIOR?

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From the very beginning of his teaching experience the writer has been haunted by the problem which confronts every conscientious teacher and educator. He has wondered whether or not the materials commonly taught in secondary schools have a vital effect on the learner. As a young and inexperienced worker in the profession he often found difficulty in answering the question, "Why should we learn that?" when it was propounded by a practical-minded adolescent whose eyes were looking into the future.

There are few recorded attempts to evaluate the effects of learning on the overt behavior of the learner. Many tests are available for probing the extent of gains in information; attitude scales and similar instruments are obtainable. Yet to this day there is a dearth of data concerning actual changes in overt behavior resulting from classroom experiences. Still remaining to be answered are such questions as: How will learning alter the things the pupil does? Can such changes be detected? Can their magnitude be estimated?

To answer these questions in part, the experimental method was used. Casual observation of ninth-grade biology pupils showed that they possessed a number of behaviors which were undesirable from the standpoint of health. At the same time it was realized that one of the nation's unsolved problems was the prevalence of communicable diseases. These two circumstances provided the foundation for experimentation.

In a preliminary study it was found that those behaviors related to the prevention of communicable diseases fell into three categories. First, there were the behaviors which could be observed directly. Second, there were a number of behaviors which could be revealed best by interviews with all pupils, since they were part of the life of all. The third group included those which affected only pupils who had been ill with a communicable disease.

Behaviors which could be observed directly included such actions as putting fingers and other foreign objects into the mouth or nostrils, biting fingernails, and rubbing the eyes with the fingers. Observations also showed that pupils almost never used handkerchiefs when sneezing, and only infrequently used handkerchiefs when coughing.

Among the behaviors which could be revealed by interviews with all the subjects of the study were such actions as washing the hands before eating, sharing bites of food with other people, and using unsanitary utensils. Interviews disclosed that the majority of the pupils did not wash their hands while at school, even before eating lunch, and that many did not wash before dinner at home. Pupils frequently passed around food out of which one or more took a bite. Drinking glasses at home were shared by other members of the family, as were towels and wash cloths (and in one case even a toothbrush).

Interviews with pupils who had been absent from school because of communicable illness resulted in significant revelations. Ill pupils did not go to bed promptly, but often came to school for several days with visible symptoms of sickness. When at home, they did not remain in bed until they were well. A physician was seldom consulted; instead, patent medicines were taken. The sick children commonly had visitors, and no precautions were taken to prevent the spread of infection either to

the callers or to other members of the family.

The observations and interviews suggested a fertile area for investigation of the effects of learning on overt behavior. All of the behaviors named were judged by competent persons to have a bearing on communicable disease transmission. To bring about desirable changes in these behaviors became a primary goal of teaching.

Study of statistics compiled by the United States Public Health Service disclosed fifteen communicable diseases of sufficient importance to be of concern to every citizen, namely chicken pox, diphtheria, gonorrhea, influenza, malaria, measles, mumps, pneumonia, scarlet fever, smallpox, syphilis, tuberculosis, typhoid fever, whooping cough, and the common cold. Information about these diseases was gathered and organized into a unit of learning materials to be studied by members of biology classes.

After the learning materials had been assembled two forms of an information test were constructed, each of which proved to have a high coefficient of reliability. By now the stage for the actual experimentation was set.

Two groups of biology pupils, each consisting of two classes, were used. One group was experimental; in this there were 62 pupils. The other group was used as a control; it numbered 64 pupils. The two groups were comparable in grade placement, age, extent of undesirable behavior, and knowledge about communicable diseases, before the experiment was begun. They were also very similar in mean intelligence quotient.

Observations to determine the pupils' pre-experiment behavior were made for ten days in biology and English classes. Each pupil thus had an observable behavior score, which was simply the total of undesirable behaviors he committed during ten periods of observation, each twenty minutes long.

By means of the interview with all pupils, scores on the behaviors previously mentioned were determined. All pupils who had been ill were interviewed upon their return to school, so that scores on the behaviors involved in that part of the investigation could be obtained.

After the pre-experiment data had been gathered, the experimental group studied the prepared material about communicable diseases intensively for twenty-eight periods. Each period was fifty minutes in length. The usual pedagogic devices and methods were used. Meanwhile, the control group was studying a unit of work not closely related to the experimental area.

At the close of the unit on communicable diseases, the observations and interviews were repeated. The information test was given again. Data were also obtained for the control group for further comparison. Twelve weeks after the end of the work on communicable diseases the information test was given again, the observations were repeated, and the interviews held once more.

So much for the techniques used in the experiment. It is impossible to give all relevant facts in a brief article; they are available in another source.[1] What were the results of the experiment in terms of changes in overt behavior? Were there any significant changes which can be attributed to the classroom experiences? Did the changes show any symptoms of being permanent?

The data of the investigation answer the above questions. Least surprising is the evidence that the experimental group made a very significant gain in information about communicable diseases, and that the control group showed practically no change in this respect. Within twelve weeks after conclusion of the study of the unit the experimental group had lost a good deal of

[1] Urban, John. *Behavior Changes Resulting from a Study of Communicable Diseases.* Bureau of Publications, Teachers College, Columbia University, New York. In press.

the increase in test score. This, too, is not without precedent.

When the scores on observed behaviors were analyzed it was found that the mean number of undesirable behaviors by experimental pupils was 20.9. Six weeks of study, however, reduced these figures sharply—to 5.5. In the final observations twelve weeks later the number showed a slight increase to 5.8. Here was real evidence of change in behavior.

In the pre-experimental observations the mean score of the control pupils was 20.1. Six weeks later the mean was 21.4; final observations yielded a mean of 21.6. It became quite apparent that the sum total of classroom experiences in this area had a real effect on the behaviors studied.

A brief illustrative analysis may be of interest. In the pre-experimental observations the total number of undesirable behaviors in biology classes by the experimental group was 1,132. Six weeks of study lowered this figure to 216; the final figure (twelve weeks after the end of the unit) was 226. At the same time the control group undesirable behaviors in biology classes rose from a pre-experimental total of 1,089 to 1,248 and finally to 1,291.

The first observations of experimental pupils showed that 32 of them coughed a total of 221 times, without using a handkerchief even once. At the close of the unit study the number of pupils who coughed was 22, the number of coughs was 101, and a handkerchief was used in 82 per cent of the cases. The final observations showed handkerchiefs used in 79 per cent of the instances of coughing. Simultaneous observations of coughing in the control group showed that in 310 instances a handkerchief was used just twice.

The interviews with the pupils were scored according to a scale from 0 to 100. On the interview held with all subjects, the mean score of the experimental group before the study of communicable diseases was 64.3; this rose to 74.6 and was at 74.0 twelve weeks later. Statistically, the gain is highly significant. The mean score of the control group on this interview was 67.3 in the pre-experimental period. It dropped to 65.7 in the six-week period, and then rose to 68.6.

The results of the interviews with pupils who had been ill may have been less reliable than the other data, for the number of subjects was smaller. Even so, the experimental-group pupils involved showed an increase from a mean score of 41.9 to 61.3. Control pupils showed no such change. Their first mean score was 46.9; their second was 45.0.

In addition to these data there was considerable oral evidence, volunteered by experimental pupils, to substantiate the belief that learning affects behavior. Most of this evidence concerned the washing of hands, the use of handkerchiefs, and the biting of fingernails. It must be emphasized that at no time were pupils exhorted to change their behavior; the investigator was careful to permit them to reach their own conclusions and to make their own applications of the scientific information they acquired. Pupils were not aware of the purpose of the interviews or observations.

A study of the data derived from this investigation seems to make the following conclusions tenable:

1. Changes in overt behaviors may be made a practical goal or objective of learning.
2. Changes in overt behavior can be estimated by techniques commonly used in educational research.
3. Although there may be a substantial loss in information, changes in overt behavior seem to be of a more permanent nature; and hence they are worth striving for.

Naturally one study does not of itself prove anything finally. Perhaps the most enduring value of the study just reported is its demonstration of the practicability of investigating a field which needs penetrating exploration. Measuring the effect of

educational experience on what the learner *does* is the ultimate—the practical—test of educational value. Were this criterion to be applied universally and with care, a great deal of curricular material might eventually be found of questionable worth.

What is actually needed is a thorough, extended investigation of the interrelationships of the various factors involved in learning. Acquisition of information, changes in attitude, changes in behavior, and changes in personal philosophy are so inextricably bound together that their interlocking ramifications must be considered as a matrix. The alert teacher will look for evidences of growth in all these complexes, and will point his work in the most promising direction. Further exploration of changes in overt behavior is necessary before much more of real benefit can be done in educational evaluation.

IN-SERVICE EDUCATION IN ELEMENTARY SCIENCE

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Today many superintendents, principals, teachers, and parents are beginning to realize the importance of science in the lives of both adults and children. Because of this, they believe that science should receive attention in the elementary school and become a part of children's living.

In schools where children are given an opportunity to ask questions, to assume some responsibility in determining the curriculum, and to help formulate plans for attacking their problems, teachers have found that young children are greatly concerned about their natural environment. The pertinent questions of these children relate to many of the big problems in their environment. These questions have challenged teachers to help children pursue their interests and to gain a better understanding of the world in which they live and their relation to it.

Frequently, there is a great lack of science experiences for children in spite of the enthusiasm of children. Many teachers feel inadequate for teaching material in the field of science and are fearful of children's questions. Some have taken very little science in high school or college. Then others find it difficult to relate the material in a college geology or astronomy course to the level of an eight or ten-year-old child. These teachers need assistance in developing a program which will insure beneficial science experiences for young boys and girls.

THE WORK OF A SCIENCE CONSULTANT

To initiate a sound and workable science program, some communities have secured the assistance of a science consultant. The consultant should act as a guide in developing a city-wide or county-wide science program with administrators, teachers, children, and parents. The consultant should not only act as a leader in giving direction to the development of science but should also help this group set up situations in which they could acquire a background of information in the various areas of the subject. Through science in-service education this group, with the assistance of the consultant, could initiate a desirable science program with continuity throughout the elementary school and also coordinated with the science work in the secondary school.

PREPARATION FOR IN-SERVICE EDUCATION

In preparing for science in-service education many important factors should be considered. The success of this adventure

greatly depends upon a cooperative attitude on the part of each individual. From the beginning each teacher, principal, and any other participator needs to feel that he is an important member of the group, that his contributions are worthwhile and that others are sympathetic toward his endeavors. To achieve these results, a situation must be created in which all members of the group have an opportunity to show initiative and resourcefulness, to participate and assume much responsibility, to feel free in expressing themselves, to give and take suggestions, to volunteer services and to become good leaders as well as followers.

The principals should be enrolled in every phase of this science in-service education. They should assume the duties as well as the benefits. Unless they have participated with many people in a variety of activities relating to this study it will be impossible for them to develop an understanding of the underlying problems, to have a basis for interpreting the proposed program, to be sympathetic to requests of teachers and children and, as leader in the school, to assist teachers in executing the plan. The principal can be of great help in developing community materials and resources because of his contacts with many parents and community workers. This cooperative plan of study offers unlimited opportunities for excellent relationships to be built up between teachers and principals. They will learn to know each other far better professionally and also socially. Undoubtedly, both groups will develop a sympathetic understanding of each other which will have far-reaching results in the administration of all school activities throughout the system. There must be no gap between teachers and principals if a science program is to be developed successfully.

It is also important that parents be given an opportunity to function in a variety of ways in this in-service program of science education. Frequently, parents offer many contributions to the development of elementary science. They may be able to acquaint teachers with community materials and resources; to give scientific information relating to personal research, experience, travel or crafts; or to share results of their experience with hobbies. Moreover, parents are in a position to give teachers information as to children's interests outside of school, the degree to which school activities carry over into the home and the reactions of children to science when not directed by a teacher. These parents who are interested in science for their children can be of great help in making educators aware of community problems and the part the school might play in helping children adjust to society in the immediate community and to society at large. Because of their various experiences, parents might make vital suggestions as to the kind of science teaching that should be done in the elementary school. Some important roles of parents in this study might be related to the ways in which children's activities at home could be integrated with those carried on in school or they might be related to ways in which parents might be helped at school in problems such as nutrition or in better use of community resources. A few vitally interested parents might make this study a much richer experience for everyone concerned.

ORGANIZATION FOR IN-SERVICE EDUCATION

After this kind of preparation for science in-service education, the entire staff should be ready to make a cooperative working plan for the study. It will be necessary for them to choose a leader and it might be advantageous to select a member of the teaching group rather than one from the principal group. A classroom teacher much interested in science, one who has had a variety of science experiences with children, shows qualities of leadership and has a dynamic personality, should make an outstanding chairman. It will be her duty

to unify and give aid in administering the plan of work.

One of the first approaches should be a discussion of the major problems involved and the possible order in which these should be attacked. Many of these problems will relate to the kind of goals that should be set up in teaching elementary science. To determine these goals it will be necessary for this group, with the assistance of the science consultant, to study the problems of the community and the events of contemporary life. The result of this study will offer a basis for determining the scientific and social values that must be held in developing a program in science to meet the needs of elementary school children in the particular community. After the goals have been determined, a science program can be organized in terms of these values.

An important experience for all members of the group will be the exchange among teachers, principals and parents of teaching experiences with children in the field of science. It is most necessary for teachers in one building to see and hear about what other teachers in another building are doing. It is also important for them to have an opportunity to meet with other people in the system and share findings. This kind of a meeting will lead to dedeveloping a broader viewpoint, increased interest, initiative and much resourcefulness in trying things with children. Every opportunity should be utilized for interplay of ideas.

Frequently small groups and sometimes large groups should come together to discuss viewpoints, ask questions, make suggestions, offer additional plans and determine new procedures. A forum might be planned in which several phases of the study could be presented by committees at different times. The results of their intensive study followed by discussions would be most helpful to the entire group. Besides these meetings, the group may wish to secure a specialist to speak to them on some problem which requires much study. As all members proceed with the work, they will be ready to make many plans in addition to those suggested here.

DEVELOPMENT OF A BACKGROUND OF INFORMATION IN SCIENCE

The in-service education should offer teachers many opportunities to build a background of information. A very thorough study should be made of the community such as: the geological formation of the region, the adaptations and interrelationships of living things (including man), and the local industries. This study should not be confined to the limits of the particular community but should include the world and the place of the world in the universe.

One method of gaining vital information is by visiting an industrial plant in the community, by studying a variety of geological formations in the particular area, by going to a park where adaptations and interrelationships of living things can be studied first-hand or by going to a city market where biological products can be observed. The science consultant will be of great help in conducting trips to points of interest and helping members of the group interpret their observations. Some teachers or parents who are well qualified to direct science groups might volunteer to assist the consultant. For instance, a teacher who is well trained in biology should be ready to take small groups of teachers to the park to study interrelationships or to other places, as one where mosquito control is being practiced.

When it is not possible to study the specimen in its natural environment it may be possible to visit a museum. Members of a museum staff will be very helpful in giving information as to all the material available to the schools, the exhibits which children can study when they visit the museum, the best procedures for working with children in the museum rooms, the method of loaning materials or how some

exhibits have been acquired and made up for use in the schools. Some museum staffs offer many other possibilities. Members of the in-service group will want to take advantage of these excellent opportunities.

The consultant and members of the group will find it highly desirable to call on specialists in numerous fields. A committee will want to visit the Board of Publice Health to determine what is being done or should be done in the community. The committee might think it advisable to invite a member of this Board to talk to the entire group. Another committee might see much value in visiting a hospital to gather scientific data on some problem. A sociologist, who is well acquainted with the community, could be secured for an evening to help interpret some of the community problems. A parent in the community might be a specialist in some field which should be studied. If so, undoubtedly he will be pleased to contribute his services by working on a committee or talking to the entire group or possibly by showing his place of business.

A SCIENCE CENTER

The science consultant will want to set up a science center as a workshop for teachers and also as a place to keep many kinds of community science materials for examination by teachers or to be loaned to the schools. As a workshop for teachers, the science center should become a place where teachers learn by experimenting, by giving demonstrations, by working with many science materials, by reading, by studying different kinds of pictures and exhibits, by discussing, by asking questions and sharing information. The materials in the science center should be accessible to teachers and principals to use in their schools or various places in their community. It might be possible for some teachers who are located near the science center to take children there if the procedure warranted favorable results.

THE CONSULTANT AND TEACHER AS CO-TEACHERS

Frequently, the teacher will have need of calling in the consultant to work with the children since no teacher can be a specialist in every area. It is more important that each teacher aim to become a specialist in the study of young children and the adaptation of the school to fit their needs and interests. However, the classroom teacher will help the children meet many of their problems in science. If the situation requires more attention than the teacher is equipped to give he should confer with the consultant. When the teacher wishes the consultant to work with the children, he should prepare the specialist by giving the necessary information for adequate interpretation and planning. During the time the consultant is in the classroom, the teacher should assume the responsibility for the children and the discussion. The children and teacher together talk over their problem with the consultant to gain information and suggestions. This procedure is advised because the teacher, having had many experiences with the group of children is best equipped to carry the discussion with them.

A teacher ond consultant working as co-teachers can obtain excellent results. When the teacher participates as the leader of the discussion she can help the children integrate their past experiences and build a background for making better interpretations. On the other hand, this does not mean that the consultant be only a specialist in science. It is most important that he, too, be a specialist in the teaching of young children. At times, he may assume the major responsibility with the children while the teacher acts as coordinator. No teacher can obtain the best results with children unless he has had much contact with each individual and so it is with the consultant.

Another way in which the consultant helps the teacher is to assist him in planning science activities. This is done if the

teacher makes a request for help or if the consultant thinks a teacher would benefit by being given some guidance as to goals, procedures, materials or bibliography. Frequently, the consultant may secure the assistance of one teacher, who has developed a certain science activity with children, to help another teacher in a similar teaching situation.

OPPORTUNITIES FOR OBSERVATION

It will be most beneficial for teachers to have an opportunity to see theory put into practice. If this type of teaching is new to a teacher he will want to see how another co-worker is studying children, using their leads in developing science activities and helping them live and learn according to scientific and social values set up by the in-service group. Teachers should be freed from their classroom responsibilities to visit teachers who are doing some outstanding science teaching. An attempt should be made to find teachers in different parts of the city who are capable of exemplifying superior science work. This will prevent the localization of science in one school or section of the community.

RECOGNITION ON INDIVIDUAL EFFORTS

The efforts of individuals to improve their capacities to do better science teaching should be recognized. Some teachers may take science courses, take additional field trips or do some exceptional work with children. These efforts should be noticed and these teachers should have an opportunity to share their experiences with others. They should report new developments in elementary science and share materials they have acquired in their courses. Later it may be advisable for these individuals to serve as advisers. This program of science teaching should be greatly advanced if the Board of Education would relieve several superior teachers, who are much interested in the development of science in their city, from their duties for a year, a semester or possibly just one month to make an intensive study of science in the elementary school.

CONCLUSION

If these recommendations are put into effect, the science consultant, teachers, principals, parents, and children will be able to organize and execute a sound and workable continuous science program in their community. The in-service science education plan should be one of continuation and not one to be pursued for a year or two and then stopped. The plan of work for the first year should involve intensive study. Later developments will be determined by the amount of progress which has been made. Young and old in the community should benefit greatly because of this adventure.

A LIFE HISTORY

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INTRODUCTION

One way of gaining perspective on the human life span is through study of biography. Most life stories, however, are written to stress one aspect of a person's activities. Very few give the picture of a life as a whole. The accompanying sketch attempts to fit together many pieces of one person's life so as to give an overview of the whole, to present a picture of one individual living through the years, changing yet always the same person. The person described is real. All the details are true. Obviously, a million other details could have been added. These might have given a clearer picture, but on the other hand, too many details would have been confusing.

In studying human development we make lists of the characteristics of the different age levels, the hazards to which people are exposed at various levels, the wide variety of social and personal achievements which are attainable. Such compilations are valuable, as are also statistical analyses to show what is true for the "average" individual. No one human being, however, lives the life of the average and no one human life exemplifies all the possibilities for human lives in general. A life history as here presented has value because it shows which of the infinite possibilities have been actually encompassed within one life; it has a kind of validity not possessed by exhaustive and comprehensive tables of data. It also has interest because of its completeness as compared with the as yet incomplete life stories of all its readers.

PENELOPE PRUDENCE

The human organism that later was to be named Penelope Prudence came into being early in the year 1864. Before that there had been only an egg cell and a sperm cell, both living but neither of them the organism which was going to live for eighty years as Penelope Prudence. In fact, if it had not united both would have ceased living within a few days or hours.

However, they did unite to form a tiny cell which would have been just visible to the eye if anyone could have seen it. Although the uniting took only a very brief time, the fact that that particular egg cell and that particular sperm cell happened to come together determined a great deal for the whole long life of Penelope Prudence, for her children and grandchildren and great-grandchildren, for all the people whose lives she touched directly, and so, indirectly but none the less definitely, for the whole world. That union of germ cells settled once and for all that this human being would grow into a girl and a woman, that is, into Penelope Prudence rather than into John or Benjamin, that she would have gray eyes and curly hair, would be above average in intelligence, and would have a thousand and one potentialities which might or might not develop depending on the kind of encouragement given them by environment. Those germ cells carried samples of all the vast number of chromosomes that had been a part of her ancestors. She was endowed at the beginning with a unique and unknown combination of possibilities that would make her like her family in some ways but always herself, unpredictable, different from any other human being that ever existed or ever would exist.

The beginning of Penelope Prudence's life then was unique, although from the outside it would have seemed merely the chance union of two ordinary germ cells to form a fertilized human egg. The next several months followed very closely the

pattern of all young human beings. The fertilized egg buried itself in the wall of a uterus. It divided again and again into many cells and increased in size more rapidly than the organism would ever again in its whole eighty years of existence. For many weeks, however, its size was not impressive. Although it increased its weight 8,000 times in the first month and 500 times in the second month, it weighed only four one-thousandths of a pound and was only an inch long at the end of eight weeks.

For the first period of existence it would have been practically impossible for anyone to have realized that this was a human being. At the beginning it had no head, no arms or legs, no trunk. No one knows exactly how long it was before the little embryonic Penelope Prudence had developed all these typically human characteristics, but we know from study of other children that it was probably two or three months. By then, if there had been an observer, he would have known that unless something happened later to disturb her development she would have the usual human form and the usual number of arms, legs, fingers, and eyes, a mouth, and a nose. Internally the beginning of heart, brain, digestive tract, muscles, bones, nerves, and other organs had been made. Up until this time she would have been called an *embryo*. From now on, her human status unmistakably established, she would be known as a *foetus*.

Many of the cells in the tiny dividing mass of cells did not become a part of what would finally be the baby. A great many took the form of covering membranes. Some of the cells secreted a fluid, and the embryo and later the foetus floated in this fluid. Other cells went to form the spongy mass of blood vessels which was the embryo's part of the placenta; still others formed the umbilical cord, which extended from the embryo to the placenta and enclosed the blood vessels and blood on which the developing organism depended for food, oxygen, and the removal of wastes. All these elaborate structures served the purpose of keeping the small being warm and safe from all but the severest shocks and of providing it with the necessities for keeping alive. At birth they would be discarded.

During the foetal period the little organism continued to develop, growing larger and heavier, every day looking more and more like a human being. By the end of the fourth month her muscles were well enough developed for her to move and she did occasionally turn and twist her whole body. Up until then her mother had not been quite sure that a baby was developing but now she could feel these movements and knew that nothing else could cause them. This baby she said was not as "lively" as some of her other children had been before they were born and did not move as often or as vigorously.

Little Penelope Prudence's development was quite normal through all this time. Her mother was working hard, cooking, sewing, keeping house for a large family, but other people helped her lift heavy things and carried in wood for her kitchen stove, so she did not put extra strain on the muscles of her abdomen which might have squeezed the uterus and the developing baby. She kept well and was out in the open air much of the time, not because she knew it was good for her and the baby, but because she lived in the country and her work took her into the garden and orchard every day. She ate plenty of food, including a great deal of milk and many fresh fruits and vegetables. This was not because she knew they contained the vitamins and minerals necessary for herself and the baby but because it was summertime and the cheapest foods were milk from the family's own cows and fruits and vegetables from their own garden and orchard. She ate large dishes of hot cereal every morning because she was accustomed to heavy breakfasts and because uncooked cereals had not yet been invented. Judged

by modern standards, she made some mistakes. She did not eat raw green vegetables because salads were supposed to be bad for pregnant women. Nor did she go to a dentist. The little Penelope Prudence got adequate supplies of most nutrients because her mother's diet was in general good and she got a fair amount of calcium, part of it from her mother's teeth. A number of people in those days believed that a mother's teeth were necessarily affected by pregnancy. One saying was "a tooth for every child."

About nine months after that first important uniting of egg and sperm cells the uterus started to contract and Penelope Prudence was born. She was born at home as most babies were in those days. No one remembers now whether there was a doctor present or not; probably not, as the place was the California frontier and there was no doctor near. There were, however, a number of women in the neighborhood who were accustomed to helping when babies were born. They made sure the baby cried immediately after she was born, thus drawing air into the lungs and starting breathing; they cut the umbilical cord which was no longer useful, since from birth on the baby would have to eat and digest her own food and get rid of her own wastes; they washed her and dressed her. It was October of the year 1864 and the days were growing shorter and cooler. The baby's ability to control her own temperature was poor; perhaps because all through her previous life she had been kept warm by her mother's body. Her mother had ready some of the clothes left over from the time when her other children were little—woolen shirts and bands, long petticoats and long dresses, warm long stockings, and woolen shawls. The little Penelope Prudence was wrapped up snugly on the first day of her life out in the world.

She was a small baby weighing a little less than six pounds. This represented an increase of many thousand times over the infinitesimally small weight of the fertilized egg she had been just nine months before. For the first two or three days after birth she lost a little weight, how much no one knew for no one bothered to weigh her every day. Her mother had plenty of milk for her and fed her whenever she cried and seemed hungry. At night she slept with her mother and at the first whimper her mother would wake and feed her quickly so as not to disturb her father who had to work hard during the day.

Penelope Prudence's development for the first few years was very like that of other children. She grew fast, though not as fast as at the beginning of her life. She learned to recognize her mother and father and her older sister and brother and to know that they would pick her up and play with her when she cried. She waved her hands and feet and turned her head and trunk, learned to hold up her head, to turn over, to reach for things, and to sit up. She stood up when she was not yet a year old and began to walk earlier than do most babies. This may have happened partly because she never was a heavy baby and could carry her own weight early. Her first tooth erupted when she was five months old, this too being a little earlier than average. She gurgled and cooed and made sounds which her family eagerly greeted as words. By the time she was two she was running about putting her fingers into everything, talking busily to herself and others, eating a wide variety of foods, controlling her eliminations except under great stress. About this time she was christened, receiving the names of her godfather's two sisters, Penelope and Prudence, a formal and dignified name usually shortened to Penny.

When she was two and a half years old another baby was born, a little sister. This meant that the mother was kept busier than ever and the five-year-old sister and seven-year-old brother took more and more responsibility for Penelope Prudence. She in turn grew to depend more and more upon them. They helped her dress, amused

her, helped her eat, and comforted her when she fell or hurt herself. They taught her new words and carried her with them into the garden and down to the creek; She played house with them under the trees at the edge of the forest, burrowed with them in the hay in the barn, learned to keep away from the horses and oxen, helped gather eggs and bring in kindling, patted the cows very gingerly while they were being milked, played with the dogs and cats, and in general explored what for a child was a very rich and exciting environment. The men who worked in her father's sawmill liked her but she was a little afraid of their rough voices and unshaven faces and preferred hanging to her mother's or sister's skirts to making friends with them. She ate at the table with the others sitting in a homemade high chair and eating small amounts of what the others ate, drinking milk instead of tea or coffee. She sometimes took naps in the afternoon and sometimes not, but she always went to bed early after undressing in front of the fireplace.

In general she was healthy, sometimes having a cold and being put to bed for a day or two, sometimes having a stomach ache, generally the result in her mother's opinion, of eating green apples or some other indigestible food. Sometimes she was "cranky," perhaps because she was tired, perhaps because she did not feel well; but her busy family had little time to worry about such things and took a certain amount of bad disposition as part of what should be expected of a baby. She grew fairly steadily, though no one weighed and measured her at regular intervals. Once in a while her father or brother stood her up against the door where the other children had been measured and cut a mark to show how tall she was.

When she was about five an epidemic of diphtheria visited the community. The fathers and mothers were terror-stricken. They could remember similar epidemics and knew that some of their babies would undoubtedly die before this one was over. They knew no way to protect the children, such as the inoculations of today and did not even isolate the small victims when they were ill. One by one Penny's sisters and brother fell sick. Penny herself and the little baby were most seriously ill with what was known as "black diphtheria." The little baby, Phyllis, did die, but after a long illness Penny unexpectedly recovered. All the rest of her long life, however, she bore the marks of the illness in her throat.

The general rule in the community was that children went to school at the age of six. Penny was very shy and cried so much at the idea of going where she would have to meet so many new people that her mother and father let her stay at home. The school was two and a half miles away, too far for her to walk anyway. And as Penny was the youngest after the death of Phyllis, the family were probably more willing to keep her at home for a little while than they might otherwise have been. At any rate her mother and her uncle taught her to read and write and do the simple arithmetic taught in the primary grades. Her sister and brother let her look at their books, and set copies and problems for her. Very soon she learned to read with sufficient ease to get great satisfaction from it. From then on all her spare time was spent lying on the floor in the room she shared with her sister or sitting out under a tree reading. Her mother always knew when she was out of sight that she was hidden away some place with a book. Many of the houses in the little settlement were papered with old newspapers and Penny loved to walk around the walls spelling out the words. This pleasure in reading remained a source of satisfaction to her all the rest of her life.

When Penny was eight she finally started to school, sometimes walking with her sister and brother across the fields, sometimes riding a little horse. The school was only one room, all the children in the

eight grades and some who were beyond the eighth grade studying and reciting there. Little Penny had a busy time in school. She finished her own lessons quickly, then she either read or listened to the older children, with the result that she advanced quickly and often recited with children much older than herself. The teachers were always men, some of them strict disciplinarians, who scolded roughly and punished severely. Penny was never punished herself but she suffered with all those who were. At times when a schoolmaster was especially loud or overstern her mother let her stay home and do her lessons with her uncle. Her older brother and sister were leaders in all games at school, but Penny always preferred to stand back. She made friends with other gentle little girls and played house with them in the corners of the school yard but was afraid of the unruly boys who sometimes laughed at them and grabbed their dolls.

She grew rapidly but always remained "small for her age" even through the spurt of growth which started at eleven and ended at thirteen at about the time of puberty. Her mother told her something of the meaning of menstruation but the whole subject of sex and reproduction remained largely a mystery, something of which "nice" girls knew nothing and in which they were not interested. Penny grew up with a rather curious dualism not uncommon to her generation, knowing many things from association with plants and animals and large families but without vocabulary for what she knew and a more or less unconscious avoidance of it even in her thoughts. She wanted to marry and have children but all these plans were remote and untinged by emotion.

She never was very active and had a poor appetite compared with her more vigorous sister and brother. Her mother said she merely "picked at her food." Along with the other children in the neighborhood she fell victim to most of the diseases of childhood—measles, whooping cough, scarlet fever, it being assumed that all children must have those and might as well get them over early. Oddly enough she did not have mumps when she was young and caught them years later from her youngest child. During a smallpox epidemic she was vaccinated by having pus from a smallpox patient scratched into her arm. She was ill for a few days but recovered quickly. The huge scar which formed under the scab stayed with her all her life and was gazed on with admiration and awe by her own children in later years.

When she was twelve her father went back to England to see his family there. He stayed for some time and when she was thirteen word came that he had died there. This left her mother to run the sawmill with the assistance of her eighteen-year-old son. He had left school earlier and the older sister attended irregularly. Penny continued to go because she got such enjoyment from it and because she was not particularly useful at home. She drove every day in a little buggy, sometimes staying all night with friends in town. She had matured and become very pretty. She danced beautifully and loved parties and a good time. The boys found her charming, and she and her sister never wanted for beaux at the neighborhood parties. Her brother grew very serious with his added responsibilities. He was a stern judge of his sisters' companions and often protested their going to parties. When they and his mother overruled him, he often escorted them to the parties and called for them afterward but generally refused to participate himself.

Penny's mother was one of those extraordinary women who ran a business successfully, yet kept time and interest for her children. From the time they were tiny children she read to them and took them for walks through the woods. All her life Penny remembered the Sunday

afternoon walks. As the children grew older the mother made companions of her daughters, especially the older one, so that they always considered her a friend as well as mother. Although one of the busiest women in the neighborhood she was always ready to act as chaperone and accompany the young people, even on drives to dances twenty and thirty miles away.

In such a remote community money did not play as large a part in everyday living as it does today. There were no convenient candy stores, soda fountains and movies for young people to patronize. Food and household supplies were purchased in large amounts at intervals of weeks or months. Penny watched her mother pay the men on Saturday night in silver dollars and gold pieces and sometimes herself handled the money paid in by men who came to buy lumber. Life was hard in many ways and money must be spent for necessities not luxuries. Yet once or twice a year Penny's mother gave her two girls a supply of ten and twenty dollar gold pieces and sent them to the nearest large town to buy clothes and whatever else they wished. When they returned she was as eager to see their purchases as they were to show them. She never criticized their choices but the girls spent carefully because they wished her approval. Among their packages were always gifts for her and for their brother.

The older sister found so much to do at home that she never entertained for long ideas of going elsewhere. Penny, however, did not like housework and did enjoy books. It was decided, therefore, to send her to normal school in a town some twenty miles distant. In the eighties this meant a great deal more in terms of separation from one's family than it would today. Penny lived for months without going home and learned to make friends for herself and to develop new interests. However, she knew she could always count to her family's support and she asked their advice and tried to keep them acquainted with all her new friends and activities.

When she was twenty her mother took her and her older sister to England for six months. Travel in 1884 was difficult. People were still emigrating to the west but pleasure trips across the continent and across the ocean were almost unheard of. The two girls never ceased talking about the trip, the cities they saw, the acquaintances they made, the fun they shared with their English cousins. All was new and strange to them, yet at the same time they realized that to their cousins they were new and strange. They looked at their own ways in the light of English customs and developed a lasting understanding of the differences, and of their cousins' inability to understand them. They laughed all their lives about the English lack of appreciation of American customs, but their laughter was tolerant and sympathetic.

On their way home their mother let them choose whether they would go by way of Washington or Niagara Falls, and it was Penny, interestingly enough, who cast the deciding vote for Niagara Falls.

Back in California Penny soon found herself a school to teach. For the next ten years she taught in a number of schools in the part of the country in which she lived, always with satisfaction to herself and the community. She liked children and liked teaching. All the rest of her life she maintained friendships made with pupils in those schools. She developed administrative competency and became principal of the two-teacher school in the town near which she lived.

Sometimes she lived at home during these years. Sometimes she boarded near the school where she happened to be teaching. Both she and her sister sang well and played the piano. Their mother bought them a piano at a time when most homes in the neighborhood, if they possessed musical instruments at all, contained only organs. Their home became a center for

the young people for miles about. They learned the newest songs of those days, they played games, they tried out the new dances. Penny sang a sweet alto, so was in demand for duets and quartets. She remained one of the best dancers in the group.

Much of the social life of the community centered about the church. The young people sang in the choir and conducted an enthusiastic young people's organization. It was the time when the temperance movement was at its height, and young women encouraged their masculine friends to "take the pledge" and wear the little white ribbon that signified their membership in the Good Templars. Partly because of her interest in this and partly because she was so constantly made aware of the evils strong drink brought to the men about the sawmill and their families, Penny remained all her life unwilling to serve alcohol in her home or to partake of it when served by others. She was always tolerant, however, of others' ideas, especially as she grew older.

During these ten years most of Penny's friends were married and several young men proposed marriage to her. She was very much interested in one, but he was a Roman Catholic and she was a Protestant, both too definitely committed to their church affiliations to give them up. He finally left the community, but they maintained a friendly correspondence through many years, in fact until his death.

In later years, however, she used to say there was never any real doubt as to whom she would marry. She would line up her suitors in her mind and whether she wished it or not the image of one man whom she had known for years and whom she did not consider especially eligible would invariably appear and the others would fade out. They were finally married in 1894 when she was thirty. Their wedding was a quiet one in the cathedral in San Francisco. Penny and her husband spent part of their honeymoon visiting the San Francisco Midwinter Exposition which contained much of the material from the Chicago World's Fair of the previous year.

The next twenty or twenty-five years were busy ones for Penny, full of activity and satisfactions, years that are hard to describe because they contained so much. Two children were born and after ten years a third. Penny lived in a small town where her husband was prominent in business and community affairs. She managed her own home, sometimes with help from the outside, sometimes alone. She devoted a great deal of time to her children, taught them to read and write before they went to school, read aloud to them from the time they were tiny children, tried to give them some of the things her mother had given her as she grew up. Almost every Sunday the family went for a walk, out into the country or down by the river. The children felt free at all times to bring their friends home for play, or music, and for all the changing interests that the years brought, and could always count on Penny's help in carrying out their projects. Penny enjoyed their companionship and made permanent friends of her children's friends. Birthdays and holidays were festive occasions, often involving trips to Penny's old home where her mother and brother and sister still lived. Trips to "the city," in this case San Francisco, were periodical affairs, the children enjoying visits with cousins to parks, playgrounds, Zoological gardens, and stores, the adults finding time when the children were in bed to attend the theater and opera.

Penny's health was generally good through these years, permitting her to lead an active and useful life with enjoyment. She suffered from migraine headaches at times, had a few attacks of what was then known as "la grippe," and was ill a few other times. Her last baby was born soon after the earthquake of 1906, and Penny was apt to excuse all his naughtiness as

he grew up by saying that he was an "earthquake baby." This baby arrived when she was forty-two, and the menopause came a few years later with little obvious disturbance to her health or her feelings. Her mother died when she was forty-eight, causing grief, of course, but not disturbing greatly the even course of her life.

In contrast to the stability of her existence through her thirties and forties, her fifties brought a number of disturbing changes. The family moved closer to the university one of the children was attending, but Penny soon moved back to the county from which they had come to be with the older boy. The father spent most of his time at his sawmill in the country where good schools were not available for the youngest child. Sometimes Penny and the little boy stayed there, sometimes they spent the school months in town. The first World War came and the older boy enlisted in the Navy. Although he never left the state the possibilities of his being in danger were a constant source of worry to the entire family. After the war he married, making the first break in the family. The war almost brought financial disaster to Penny's husband, and he moved about from place to place, operating one sawmill after another, opening up a chrome mine, managing an orange grove. The oldest daughter was at work, the youngest child went to boarding school. A fire destroyed Penny's home and all her choicest possessions.

All these changes were very hard for Penny to meet. All her life she had been able to depend on others and, out of this fundamental security, in her turn to help others. She was confused and puzzled, finding no place for herself. Her family felt responsible for helping her to find security, yet were at a loss as to how this could be done. Then, to the amazement of all, she dug out her teacher's certificate from her trunk, found herself a school and started to work. Some of her methods were old-fashioned; but she loved and understood children, was gentle and patient, and spent her spare time reading about modern methods and visiting schools. She bought herself a small car and learned to drive it, although she never trusted herself or the car and always seemed relieved when she arrived safely at her journey's end. She lived in odd places near the one-room schools in which she taught, was independent, and made herself new centers of interest. So she spent the better part of ten years.

Her bodily movements were slowing through these years. She could not walk far or fast or do many of the things which had made her children's friends label her "a good sport." She had her first experience with a hospital when a small and nonmalignant growth was removed from the uterus. She had worn glasses at times for a number of years because of a slight astigmatism but now she had to use glasses for all reading or close work. The headaches of her earlier years occurred only very rarely. She began to realize that she was not hearing what people said at times. More and more of her leisure time was spent in reading.

At sixty-eight her years of independence came to an abrupt end when she suffered a cerebral hemorrhage. For days she lay helpless and unconscious. Then gradually her strength came back, as well as her ability to think and to speak. At first she was not interested in recovering and had to be stimulated by others to make the effort required to walk and move about. She expected to die soon and wanted to go back to her childhood home. Finally her family took her back to the old place in the woods where her brother and sister were still living alone under very much the same conditions which had formed their way of living as children, though the sawmill no longer ran and the workmen had all moved away. Penny was not always happy in the

old home where the older brother and sister tried to rule her life as they had when she was a tiny child. To them she seemed still the little sister who should not read late at night and could not be trusted with responsibilities. She rebelled at their domination but would not leave them and developed unexpected strength in her desire to make life easier for them. The brother was blind and penurious, the sister frail, so Penny cooked, cleaned, even carried wood and water. For all the years of her life after her "stroke" she tottered when she walked but rarely fell. Little hemorrhages had formed in the blood vessels of her eyes, so her sight was poor and not correctable by glasses but she persisted in reading. Her hearing became poorer and poorer. She did not insist on people's speaking more loudly but watched quietly "from the side lines," participating only when talk was directed toward her. Her husband spent most of his time in the wooded country that he loved, living a rough life which Penny could not share. He came to be with her at frequent intervals and always grew restless in a few days or weeks and returned to his cabin and woods where he could occupy his hands and mind in active work. Reading and listening to the radio constituted Penny's chief diversions with scattered visits to her children. This phase of her life came to an end when her brother died and she went to live with one of her sons. She was then seventy-two.

The circle of her interests grew smaller and smaller through the remaining years. She was passionately attached to her family and inclined to worry about their welfare. Her small income was generally spent for her husband and children. She was afraid her small grandson did not "like" her, a groundless fear as she spent most of the time when they were together reading to him, often the same stories over and over as he demanded them, playing games and answering his questions. He wondered at her tottering steps but cried when she left for a short space of time. After her granddaughter was born Penny was devoted to her and the baby returned the affection, finding "Dwandmummie" an entertaining companion, a steadfast support over which to climb, and a comforting pillow on which to rest. Penny insisted on doing simple things about the house, washing dishes, ironing towels, making her own bed, and caring for her own clothes. She had constantly to be planned for but she made a real contribution to the smooth running of the household and provided company for her daughter-in-law who would otherwise have been alone much of the time. Her genuine devotion to her family and her friends was an intangible asset in their lives which was sorely missed when it was finally gone. All hoped that the little grandson and granddaughter would retain some memory of their grandmother and her devotion to them.

Her last years were marked by several recurrences of cerebral hemorrhage in mild form. Each left her a little weaker, a little less able to do things for herself, a little less in touch with reality. She did not always distinguish between what was real and what was the horrible product of her imagination. She grieved and was hurt about things that never happened; her memory was very poor, although she always remembered her family and old friends and trusted them as a child trusts those who care for it. The last flooding of blood through the brain come while she was asleep and, although she breathed for a few hours longer, the overstrained heart grew weaker and weaker and finally came to a slow stop. The life started those many years ago by the seemingly chance meeting of an infinitesimal sperm cell with but a slightly larger egg cell was ended, the life which began with the end of a great civil war and had seen the nation become involved more and more deeply with other nations until at last it went out with a second world war. Mysteriously the little baby, the shy little girl, the charming

young woman, the helpful woman of mature years, the gentle and unexpectedly steadfast older woman, the retiring slow-moving old lady did not exist, any more than they had existed before that meeting of sperm and egg. Yet between that the beginning and that end was the reality of a human life, and who can say that reality once existing no longer exists.

QUESTIONS FOR DISCUSSION

1. What care was taken of Penelope Prudence in her prenatal life? Compare this with modern standards. What influence may her prenatal life have had upon her later life?
2. Compare the care given Penelope Prudence with care given babies today. Compare her development with the development of most babies.
3. Discuss Penny's health in early and later childhood. Discuss the health care given to her at home and at school.
4. What influences affected Penny's social development in early childhood? How did this social development affect her later life?
5. What things about Penny's education were advantageous to her development? What things were disadvantageous?
6. Was Penelope's education concerning sex and reproduction adequate for the time in which she lived? Would your answer be the same if she had been exposed to the influences operating today? What safeguards did she have which are not usual for girls of today?
7. How did Penelope's experience as an adolescent and young woman serve as preparation for vocational success, social adjustment, use of money, and family life?
8. What contributions did Penelope Prudence make to family and community life during year years of maturity? Could her education have done more to make her an asset in her family and community?
9. How did Penny meet the frustrations attendant upon her later maturity. What experiences in her earlier life influenced her behavior at that period?
10. Were the changes in Penny's life as she grew older typical of what happens to most people? Could her earlier education and experiences have contributed more to her happiness in old age?
11. Throughout her long life Penelope Prudence had to make many adjustments to new ways of living. Upon what experiences did she draw in rebuilding her life? Were the adjustments she was called upon to make of the same kind as must be made by others?
12. In what ways did Penny evidence a desire to carry her share of responsibility to others at various periods of her life?
13. Was Penelope as a grandmother a trouble to her family? Did she contribute to its happiness? Evaluate her influence on the family life.
14. Do you think Penelope Prudence lived a successful life? Give your reasons.

Abstracts

GENERAL EDUCATION

BOLTON, FREDERICK E. "Wasteful Foreign Language Requirements." *School and Society* 56: 1–4; July 4, 1942.

Only tradition makes a study of a foreign language a requirement for graduation in most high schools. The author says that now is the time to remove such retarding traditions. On the other hand he believes that foreign languages should be taught, but only for those having some aptitude and a genuine interest in the learning of foreign languages.

—C.M.P.

CAWTHON, ANNE. "A Personal View of Secret Societies." *School Activities* 14: 10–12; September, 1942.

The author discusses the arguments so often used by members as to the values of secret societies and stresses the point that there are no values or so-called values that are not or could not be as well or be offered better by the school itself. And far too many times secret societies are positively detrimental.

—C.M.P.

KNIGHT, EDGAR W. "The 'Messianic' Invasion of the South After 1865." *School and Society* 57: 645–649; June 5, 1943.

Educational leaders in the north following the close of the Civil War in 1865 had a "Messianic" zeal to reform and re-educate the South. The author quotes Samuel S. Greene, President of the National Teachers Association, and others in proof of this "uplift" attitude. Naturally, the South then resented, and to some extent still does, this attempt at "high-handed" educational uplift. Not understanding the spirit and the feelings of the South, much bitterness and ill-feeling resulted. The authors says that similar conditions exist relative to suggested attempts to "re-educate conquered axis countries." More harm than good would result from our attempt to impose our educational and political views upon a resentful, conquered nation.

—C.M.P.

WENGER, ROY. "Motion Pictures in Teacher Education." *Educational Research Bulletin* 22: 90–96; April 14, 1943.

This article is based on a survey to find out the facts about film use in the College of Education at Ohio State University. About half of the 187 instructors use films and rate them as important materials in the instructional program. Motion picture materials are not readily available and each instructor has the responsibility in learning about films and in arranging for their presentation.

—C.M.P.

EDUCATION AND WAR

GRAHAM, FRANK P. "Global War—The Peoples' Revolution." *School and Society* 56: 365–370; October 24, 1942.

Truly this is a global war involving all continents, seas, and skies, as well as all the people and all of their industries and institutions. Five million casualties are already the toll of total war on the Russian battlefields. Five million Chinese men, women, and children have been killed. Science, technology, agriculture, finance, industry, commerce, transport, communication, the press, the professions, government, education, and religion are all parts of the total war. In a real sense it's the people's revolution against the fascist counter-revolution.

—C.M.P.

SONNEDECKER, GLENN. "Soybean Boom." *Science News Letter* 42: 362–363; December 5, 1942.

Soybeans, one of the oldest crops used by man (described in Chinese writings 3,000 years B.C.) have very recently become a very important American crop. This year about 200,000,000 bushels were grown on 14,000,000 acres. Few crops have a greater variety of uses. Among these are: rubber substitutes, plastics, vegetable oil salads, sausages, soups, bread, whole milk substitute, grits, paints, fiber, etc.

—C.M.P.

FRIEDMAN, WILLIAM S. "Wings of Victory." *Popular Science Monthly* 142: 70–83, 222–227; January, 1943.

This is an unusually fine article on American airplanes. Numerous diagrammatic sketches are included. There is detailed information of the eleven main types: Boeing Flying Fortress, North American Mitchell, Martin Marauder, Consolidated Liberator, Lockheed Lightning, Bell Airacobra, Douglas Havoc, North American Mustang, Republic Thunderbolt, Vultee Vengeance, and Curtiss Warhawk.

—C.M.P.

DREHER, CARL. "Explosives for War." *Popular Science Monthly* 141: 73–76, 210; September, 1942.

The making of smokeless powder is a complicated process in industrial chemistry. Extremely close chemical control is required at every stage as the cotton is changed into nitrocellulose or guncotton. It takes more than a half pint of alcohol to make a pound of powder. An army of 1,200,000 men in the field needs 600,000 pounds of powder a day.

—C.M.P.

WAITT, ALDEN H. "Smoke—A Weapon for Attack as Well as Defense." *Popular Science Monthly* 141: 54–58; September, 1942.

Smoke is being used effectively as a weapon of attack, as well as defense. Smoke producing chemicals include: white phosphorus, titanium tetrachloride, sulfur trioxide in chlorsulfonic acid and diphenyl chlorarsine. Methods of loading include cylinders, aerial bombs, Livens projector bombs, mortar bombs, grenades, candles, airplane spray, and shells. Dark clouds are more effective than light clouds.

—C.M.P.

SINKS, ALFRED H. "Chemists Fight on 1,000 Fronts." *Popular Science Monthly* 142: 58–63; February, 1943.

This article describes a few of the ways in which chemistry is being used in winning the war—T.N.T., high-octane gasoline, synthetic rubber, teargas, poison gas dyes, plastics, medicines, drugs, soapless soaps, and so on.

—C.M.P.

JEWETT, FRANK B. "The Mobilization of Science in National Defense." *Science* 95: 235–241; March 6, 1942.

In this article the Chairman of the Board of the Bell Telephone Laboratories sketches the set-up of organized civilian research and development created for the war emergency. The scientific departments of the armed forces, the research activities of industrial and private laboratories, and the science laboratories of colleges and universities are turning their attention increasingly to problems of pure and applied research.

—C.M.P.

STAFFORD, JANE. "Emergency Action." *Science News Letter* 41: 55, 58; January 24, 1942.

This article tells what to do in case of injury. Rules for first aid in life saving are given. How to use artificial respiration, stop severe bleeding, and treat shock are given.

—C.M.P.

AUCHTER, E. C. "Agricultural Science and the People's Welfare." *Science* 96: 283–289; September 25, 1942.

This exceptionally fine article was an address given at the Second Inter-American Conference of Agriculture at Mexico City, July 6, 1942. The war has placed a huge task on agricultural science, a task not likely to be lessened immediately upon the end of the war. The need for maximum efficiency in present tasks and at the same time as great a demand for more diversification and even new products, has placed upon agriculture a tremendous job. There is need of social awareness by, and a coordination of effort among, all agricultural scientists.

—C.M.P.

WALTERS, RAYMOND. "Statistics of Attendance in American Universities and College, 1942." *School and Society* 56: 591–602; December 19, 1942.

College enrollment this fall was 9.5 per cent lower than in 1941 and 18 per cent lower than in 1940. Total enrollment in 667 colleges and universities was 746,922 full time students. Data are included for each individual college and university as well as for sections.

—C.M.P.

CHRISTOFFERSEN, R. O., AND WITTICH, W. A. "Navy Statistics on Mathematics Retention—A Challenge to the School." *School and Society* 56: 502–504; November 21, 1942.

In an examination given to 3,052 naval recruits, a group of 800 high school graduates scored 56.1. This article points out that "refresher" courses in the senior year would undoubtedly greatly increase test score marks as earlier low marks are largely due to the presence of a forgetting factor.

—C.M.P.

KOESTER, LEONARD. "The Weakest Spot in Our National Armor." *School and Society* 55: 337–340; March 28, 1942.

The weakest point in our national armor is the failure to study the languages of other nations so as to be able to speak their language and really understand the peoples—their dialects, literature, art, music, history, great men, laws, industry, and so on. The Germans and Japs really know the other folk, hence their ease of penetration—economic, political, social, military.

—C.M.P.

VANDE WATER, MARJORIE. "Picking Flyers." *Science News Letter* 42: 234, 236, 238; October 10, 1942.

This interesting article describes some of the psychological tests the army uses to choose cadets likely to succeed as navigators, bombardiers and pilots.

—C.M.P.

STAFFORD, JANE. "Victory Meals." *Science News Letter* 42: 218–219; October 3, 1942.

Meatless days ahead does not mean the American diet will be deficient in protein. Milk, eggs, and cheese are excellent substitutes, but peanuts and soybeans are excellent additions. The latter two will be increasingly used.

—C.M.P.

Book Reviews

MYTINGER, CAROLINE. *Headhunting in the Solomon Islands Around the Coral Sea.* New York: The Macmillan Company, 1942. 416 p. $3.00.

This is the most recent travel book about that region recently so much in the news in American war despatches—The Solomon Islands around the Coral Sea. This is the fascinating account of two young women's trip, the two women being the author Miss Caroline Mytinger and the other Miss Margaret Warner. Miss Mytinger's main purpose, successfully accomplished, for such an unorthodox venture which consisted of only the two women, was to paint portraits of the native headhunters of those regions. Needless to say their travels were marked by much comedy, sad experiences, and ever present danger. Dangers from disease (which they did not escape), storms, fire, earthquakes, from the natives themselves, and usually from the steaming heat and less often the extreme drought—are all vividly portrayed. Islands and places visited include many places where Americans are now bitterly engaged in hand-to-hand fighting with the Japs. Guadalcanal, New Britain, Papua, New Guinea, Big Buka, and Rabaul.

—C.M.P.

NEEDHAM, JOSEPH. *Time, the Refreshing River.* New York: The Macmillan Company, 1943. 280 p. $3.75.

Time, the Refreshing River consists of a series of essays and addresses written between 1932 and 1942. Titles are as follows: (1) "Metamorphoses of Scepticism," (2) "The Naturalness of the Spiritual World: A Reappraisement of Henry Drummond," (3) "Science, Religion and Socialism," (4) "Laud, the Levellers, and the Virtuosi," (5) "Pure Science and the Idea of the Holy," (6) "Thoughts of a Young Scientist on the Testament of an Elder One," (7) "The Biological Basis of Sociology," (8) "A Biologist's View of Whitehead's Philosophy," (9) "Evolution and Thermodynamics," and (10) "Integrative Levels; A Revolution of the Idea of Progress."

—C.M.P.

HOLMES, HARRY N. *Strategic Materials and National Strength.* New York: The Macmillan Company, 1942. 106 p. $1.75.

Long before the present war it was readily apparent that we had insufficient amounts of certain very essential or strategic materials necessary for the common welfare. Leith and others had long ago listed such strategic materials. But the public by and large and many of those in government office were blandly ignorant or unconcerned or both. Negligence of certain officials in obtaining a good stockpile of evident deficient strategic materials in the pre-war period has up to now, and likely will go unpunished. Yet these acts of omission in some respects have been more detrimental to our war effort than all the activities of the isolationist or even the Nazi propagandist. Rationing was necessary much before it should have been, had some persons responsible planned adequately.

In this book Dr. Holmes discusses sources and prospects of many rationed materials. Most materials have now become strategic, even some that less than a year ago were being delimited as a necessary national policy. The thirty most vital raw materials listed by Dr. Holmes include: aluminum, ammonia, antimony, asbestos, chromium, cotton, coal, copper, fats, food, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, petroleum, phosphates, potash, rubber, salt, starch, sulfur, wood, wool, tin, and tungsten.

—C.M.P.

DULL, CHARLES E., AND NEWLIN, IRA G. *Fundamentals of Machines; Fundamentals of Electricity.* New York: Henry Holt and Company, 1943. 547 p; 456 p. $1.48 each.

These are pre-induction courses at the foundational level prepared at the request of the War Department and the U. S. Office of Education. They are intended for the twelfth grade and are for one semester each. In the preface the authors state the reasons for high school pre-induction courses in the words of General Somerville: "Our Army today is an army of specialists. Out of every 100 men inducted into the service, 63 are assigned to duties requiring specialized training. We aren't getting those 63 specialists through the induction centers. Modern warfare dictates that we must have them."

Many illustrations, demonstrations and diagrams supplement the textual material. At the end of each chapter is a list of scientific terms for drill, self-testing exercises, questions and problems. At the end of the text is a glossary of scientific terms, laboratory experiments, a series of useful tables, and a mathematics refresher. The material is more comprehensive than that found in high school texts, and naturally has a wartime slant.

—C.M.P.